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SEPTEMBER 1951

IDENTIFICATION OF LF/MF NON-DIRECTIONAL RADIO BEACONS UTILIZING FREQUENCY MODULATION (F_1)

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FOREWORD

The information contained in this circular concerns a proposed method of identifying LF/MF Non-Directional Radio Beacons and LF/MF Radio Broadcasting Stations by utilizing frequency modulation (F_1) techniques for conveying the identity in such a manner that certain difficulties experienced with existing A_1 and A_o/A_2 methods of identification are eliminated.

The material was submitted to the Fourth Session of the Communications Division of ICAO by the Government of France. The Division recommended that the material should be disseminated to States for their information and for the purpose of encouraging an operational evaluation of the proposed method of identification.

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CHAPTER I

IDENTIFICATION OF NON-DIRECTIONAL BEACONS

SUMMARY

1.1 Problem of Radio Beacon Identification

Historical

ICAO Doc 2553 - COT 26 (Section IV - paragraph 5.2) recommended that all non-directional beacons use A_0/A_2 emission in order that the carrier should never be interrupted during transmission of identification since interruption of the carrier causes the automatic direction finder to drift during the periods of interruption, particularly in cases of interference. (With an A_1 system, the ADF tends to align itself with the azimuth of the interfering station during the keying periods.)

In accordance with these provisions, during 1948 a certain number of beacons equipped with modulators (mainly American transmitters) were set up on A_0/A_2 in the European and African Region by the French authorities. It was not long before complaints were received from airlines (TAI), particularly those operating over the Sahara area. In effect, the A_0/A_2 system advocated by ICAO has certain disadvantages. These are as follows:

a) Considerable bandwidth required (2 to 3 kc/s). The A_0/A_2 system transmitters which are provided in this instance utilize grid modulation only, which does not modulate the carrier suficiently. Satisfactory A_0/A_2 operation requires a depth of modulation corresponding to at least 80%.

b) It is difficult to read the identification signal owing to the insufficient depth of modulation at long distances and when there is interference. This is very inconvenient when long range beacons are used for short distance navigation with an ADF, as well as for long distance navigation with manual D/F.

c) The addition of a modulator capable of providing sufficient depth practically doubles the cost of the equipment and the power requirements of a beacon of given range. This is out of the question for radio beacons which are to be operated in desert areas.

For low power beacons and marker beacons the complexity and increase in operating costs of A_0/A_2 system equipment is also a factor for consideration.

Following these comments which were presented by France to the ICAO preparatory Meeting on the MF Geneva Plan which came into force on 15 March 1950, it was accepted that medium and long range beacons in the EUMED Region would continue to operate on A_1. Moreover Annex 10 only provides a Standard regarding A_0/A_2 type emission for locators.

Therefore it appears that, as no fully satisfactory solution has yet been adopted, the problem of radio beacon identification still exists.

1.2 Identification of Broadcasting Stations

It is well known that, for "en-route" navigation, Broadcasting Stations are often used as beacons in conjunction with an ADF. However, this method, although very interesting, is not to be recommended in the present circumstances, owing to the difficulty involved in identification of these stations.

During the last war, the Germans used to interrupt their broadcasts to transmit identification signals.

In 1941 the American authorities on their side investigated a more discrete method of identification. This research, interrupted by the war, was resumed in 1946, and in 1948 the American "AERONAUTICAL RADIO INC" tested a method involving modification of the ADF equipment. (See Chapter V.)

The Broadcasting carrier wave was modulated at a very low frequency (40 c/s) and at a very low percentage (5%). When received, the 40 c/s. signal operated a 1000 c/s. oscillator. As a result of complaints from listeners it became necessary to reduce the percentage of 5% to 3%. With that, the device ceased to be of any value as the identification could only be received over short distances and the principle was abandoned.

It appears today that a solution can be adopted, which solves both the problem of beacon identification without interrupting the carrier and that of identification of broadcasting stations. This is frequency shift modulation or F_1 modulation.

1.3 F_1 Modulated Beacons

This system consists in shifting the frequency of the radiated carrier about one hundred cycles at the identification keying rate. (See Chapter II.)

The advantages of this type of modulation are as follows:

a) reduced frequency spectrum space required;

b) no interruption of the carrier during identification keying;

c) possibility of transmitting a signal inaudible to Broadcast listeners but which can be used by navigators for identification purposes.

If such a method of identification could be applied to all European stations with an exclusive frequency, then it would be possible to ensure full coverage by powerful non-directional beacons suitable for en-route navigation. The aerodrome beacons could then be reduced in power so as to yield a range of 50 nms for final homing. This system is particularly valuable in view of the complete deadlock we are facing in the EUMED Region with regard to the LF/MF part of the radio frequency spectrum.

Nevertheless there is a serious obstacle to the immediate application of this system on an international basis; most ADF receivers are equipped with a heterotone device for reception of A_1, consequently reception of F_1 signals is not possible.

However, certain airlines, and Air France in particular, have envisaged, for other reasons, the addition of a BFO to the ADF, which permits F_1 modulation to be received.

Furthermore, the latest American Bendix ARN6 and RCA AVR21 automatic direction finders are equipped with a BFO on the antenna and D/F positions.

Therefore it appears that a recommendation to modify ADF equipment would not give rise to serious objections.

In any case, one cannot compare the minor nature of the proposed modification (addition of a BFO costing about 20,000 francs) with that involved in the adoption of the equipment described by the American ARINC, had it been adopted.

CHAPTER II

STUDY OF AN MF FREQUENCY SHIFT MASTER OSCILLATOR, FOR F_1 RADIO BEACON IDENTIFICATION

WORKING PRINCIPLE

2.1 Standard crystal oscillator with frequency shift

In the oscillator schematic diagram in Fig. 1, it can be seen that the frequency of oscillation of crystal Q is a function of the value C of capacities CV_1 and CV_2.

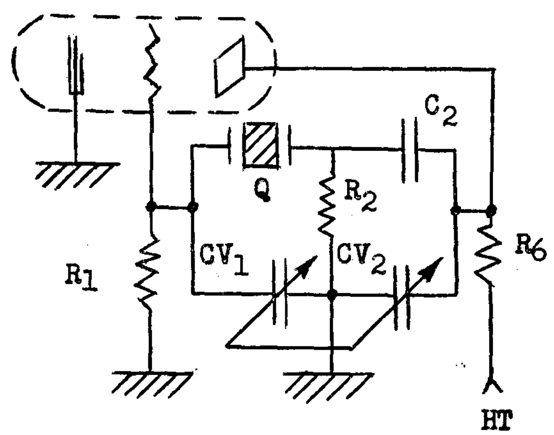
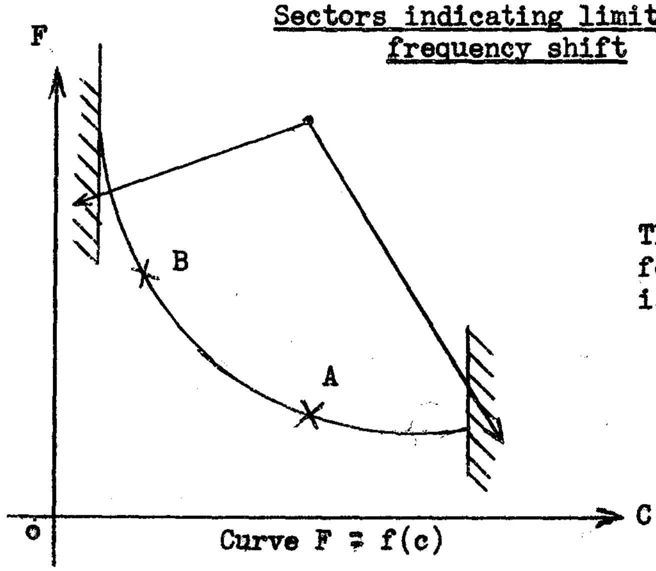


Fig. 1

The curve F = f(c) in Fig. 2, expresses the law governing this frequency shift.



The curve F = f(c) for a 396 kc/s. crystal is given in Fig. 8

Fig. 2

Values for capacities CV_1 and CV_2 are generally chosen in such a way that the unit is operated at a frequency corresponding to point A. Thus, in view of the stability of this segment of the curve, spurious variations in capacities will not result in frequency variations.

Furthermore, point A is sufficiently far away from the limiting sectors to ensure stability.

Therefore, it may be seen from the curve, that in order to obtain any desired modulation F_1, one need only switch a capacity in parallel with CV_1 and CV_2, at the keying rate.

An elementary method of doing this would be to switch a capacity in parallel with the crystal, either manually, or by means of an electro-magnetic relay. The latter, of course, would be the neater method.

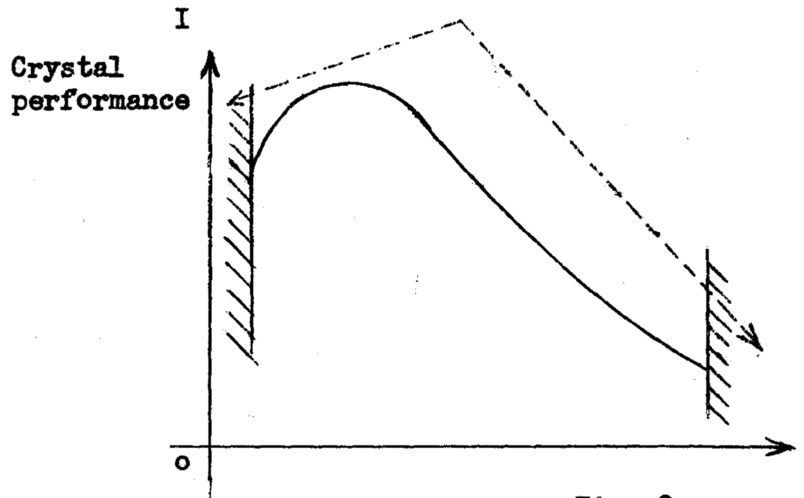
The point of operation, corresponding to the steady frequency, will then be located at A, in the stable portion of the curve in Fig. 2, with frequency shift to the higher frequency values (point B).

The frequency shift thus obtained is relatively small. A 400 kc/s. crystal, for instance, could not shift in frequency much more than 100 c/s, without ceasing to oscillate.

2.2 Spurious amplitude variations

A variation in capacities CV_1 and CV_2 also produces a variation in the performance of the crystal. The law governing this variation, $I = \varphi\ (c)$, is shown in Fig. 3.

Sectors indicating oscillating limits



The curve $I = \varphi\ (c)$ for a 396 kc/s. crystal is given in Fig. 9

Fig. 3

This variation in the performance of the crystal would, in turn, bring about an amplitude variation. Thus, variations of capacities CV_1 and CV_2 would produce simultaneously both frequency and amplitude modulations.

Since the object is to produce frequency modulations alone, the master oscillator must be followed by a clipping stage.

2.3 Electronic relays

The diagram in Fig. 4 illustrates a simple system.

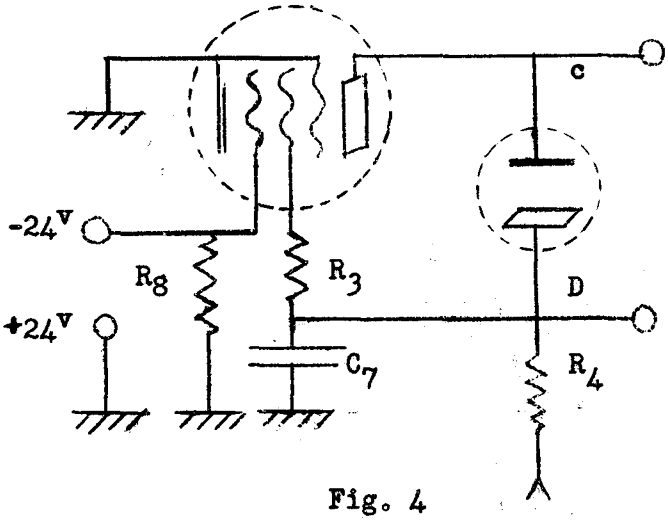


Fig. 4

When grid G_1 of the pentode is not at a large negative potential, anode current will flow across the interval CD. If grid G_1 is at a sufficient negative potential, this current will not flow.

2.4 Electronic switching which will cause a frequency shift in the oscillator

The schematic diagram of the system is given in Fig. 5.

Capacity C_7 is large compared to capacities C_8 and C_9. This means that when each 6AL5 tube is conductive, capacities C_8 and C_9, for high frequencies, are in parallel with CV_1 and CV_2, and the master oscillator frequency is shifting within the limits indicated in paragraph 2.1.

Coupling with the buffer stage is small, in order to ensure proper isolation in the master oscillator circuits (C_{13} = 25 pF).

Capacity C_{11} acts as an integrator, which avoids blocking of the oscillator tube during transition intervals. It has been calculated in such a manner as to ensure a low time constant, for diode blocking and unblocking, and to provide abrupt switching. If this were not done, capacities C_8 and C_9 would progressively enter into the circuit, and would result in a progressive variation in the master oscillator frequency which, in turn, would result in a whining sound when receiving identification keying.

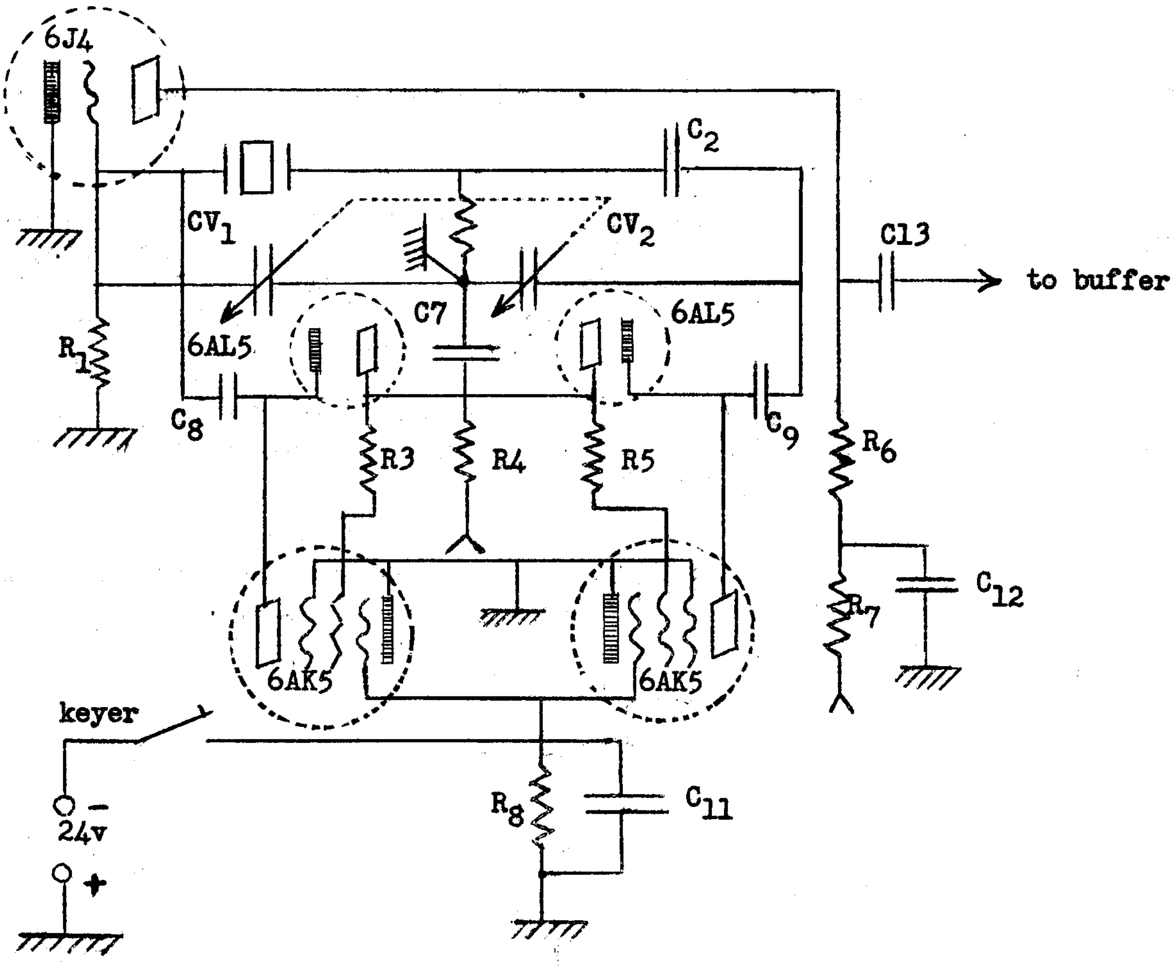


Fig. 5

2.5 Limiter stage

The circuit diagram is given in Fig. 6.

A pentode, (6AK5) (unbiased), functions statically at the grid current limit.

Dynamically, the grid current causes a potential to appear across the resistance R_{12}, which is a function of the signal amplitude.

In this manner, a voltage appearing in the anode circuit is regulated. (See curve in Fig. 10.)

The distortion which results from clipping is not troublesome, since filtering of objectionable harmonics is achieved through the presence, in the anode circuit, of a transformer whose circuits are tuned to the basic frequency.

Coupling of the two tuned circuits is relatively tight, and the voltage at frequency F + 100 c/s. suffers negligible attenuation, when compared to the voltage at frequency F.

Thus, the voltage emerging from this stage has a constant amplitude free of distortion.

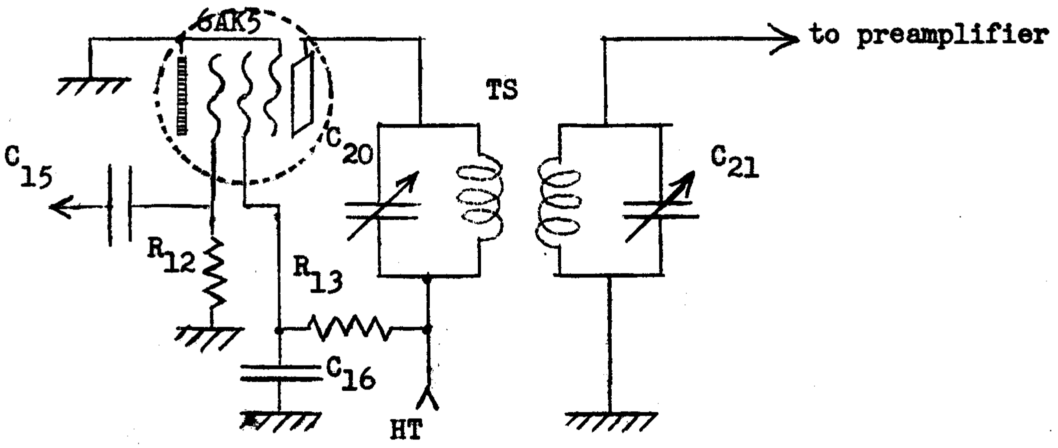


Fig. 6

2.6 Main diagram - Nomenclature and voltages in use

The main diagram appears in Fig. 7.

The voltage and current readings are as follows:

	Ip	Vp	Ig^1	Ig^2	Vg^2	Vg^1
6J4 (osc)	1	80^v	0,1	-		
6AK5 Relay	3 0	40 150	- -	1 0	25 150	0 -24
6AK5 Buffer	0,6	170	-	0,2	40	
6AK5 Limiter	5	150	-			

The characteristics of the components used are given in the following table.

R1	50K ohms		CV1	
R2	1Mégohm		CV2	2x80pF
R3	15K ohms		C3)	omitted on the original
R4	15K ohms		C4)	model
R5	15K ohms		C5	40 pF
R6	50K ohms		C6	90 pF
R7	50K ohms		C7	0,01 micro F
R8	50K ohms		C8	120 pF
R9	5Mégohm		C9	120 pF
R10	500K ohms		C10	0,01 micro F
R11	100K ohms		C11	0,01 "
R12	250K ohms		C12	0,01 "
R13	50K ohms		C13	25 pF
			C14	0,01 micro F
		20w	C15	700 pF
			C16	0,01 pF
	Cv - Cv_1 on TS			

N	Tubes	Function
1	6J4	Master oscillator
2 2	6AL5) 6AK5)	Electronic relay
1	6AK5	Buffer
1	6AK5	Limiter

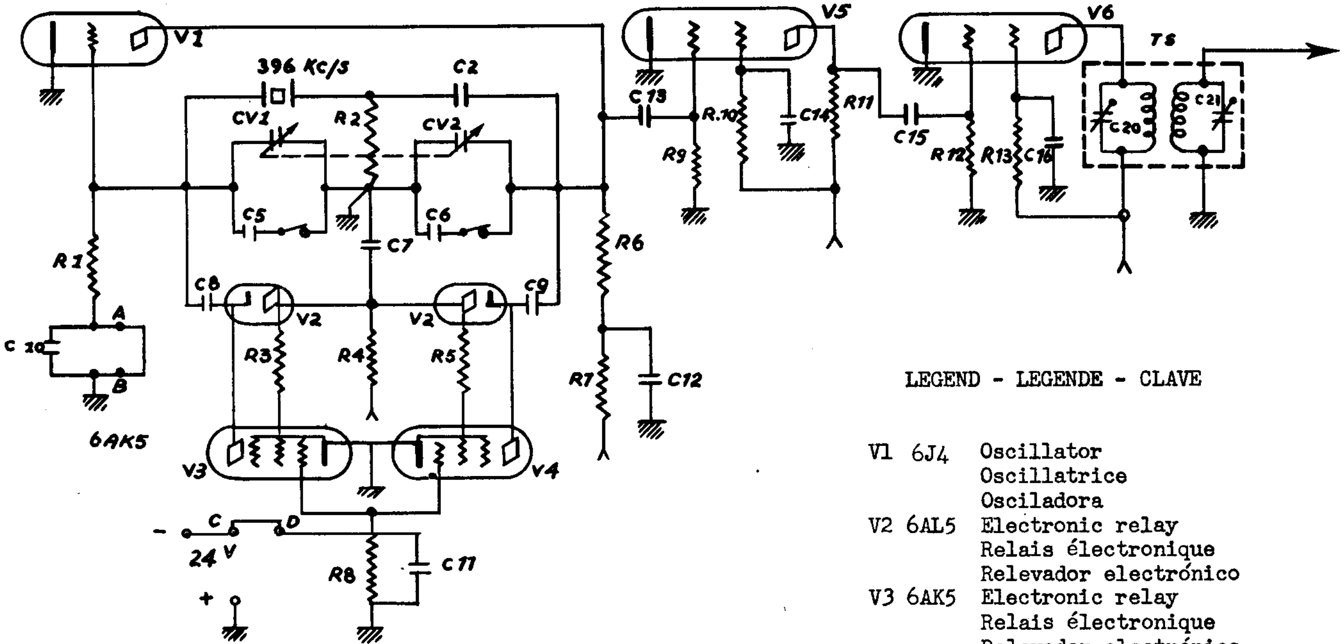
Paris, 1st February 1951

Approved by: Ingénieur General, Directeur du Service de la Navigation Aérienne,

Signed: P. Grenier

Prepared and presented by:
G. Charot
Ing. T. T. A.

SNA - 1/2/51 - n° 1743



LEGEND - LEGENDE - CLAVE

V1	6J4	Oscillator Oscillatrice Osciladora
V2	6AL5	Electronic relay Relais électronique Relevador electrónico
V3	6AK5	Electronic relay Relais électronique Relevador electrónico
V4	6AK5	Electronic relay Relais électronique Relevador electrónico
V5	6AK5	Buffer Séparatrice Separadora
V6	6AK5	Limiter Limiteuse Limitadora

H.F. OUTPUT VOLTAGE AT NO LOAD: 50 volts
TENSION H.F. DE SORTIE A VIDE: 50 volts
TENSION H.F. DE SALIDA EN VACIO: 50 voltios

H.F. OUTPUT VOLTAGE WITH LOAD (1): 11 volts
TENSION H.F. DE SORTIE EN CHARGE (1): 11 volts
TENSION H.F. DE SALIDA EN CARGA (1): 11 voltios

(1) The load consists of one triode 6V6 tube
La charge est constituée par une 6V6 montée en triode
La carga está constituida por una 6V6 montada como triodo

Fig.7.- SCHEMATIC CIRCUIT DIAGRAM
SCHEMA DE PRINCIPE
ESQUEMA DE PRINCIPIO

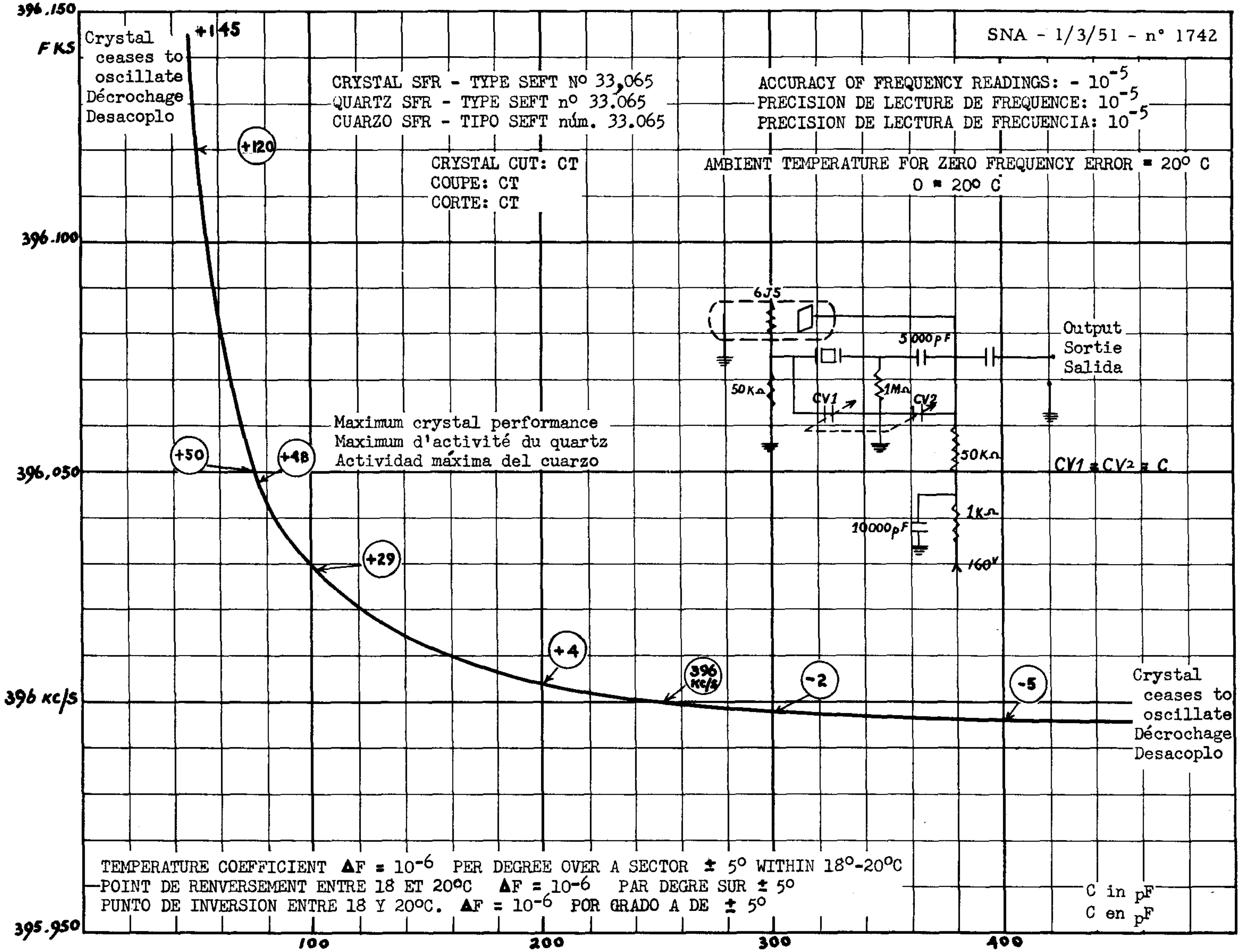


Fig. 8.- FREQUENCY SHIFT AS A FUNCTION OF THE VARIATION OF CAPACITIES CV_1-CV_2

VARIATION DE FREQUENCE EN FONCTION DE LA VARIATION DES CAPACITES CV_1-CV_2

VARIACION DE FRECUENCIA EN FUNCION DE LA VARIACION DE LAS CAPACIDADES CV_1-CV_2

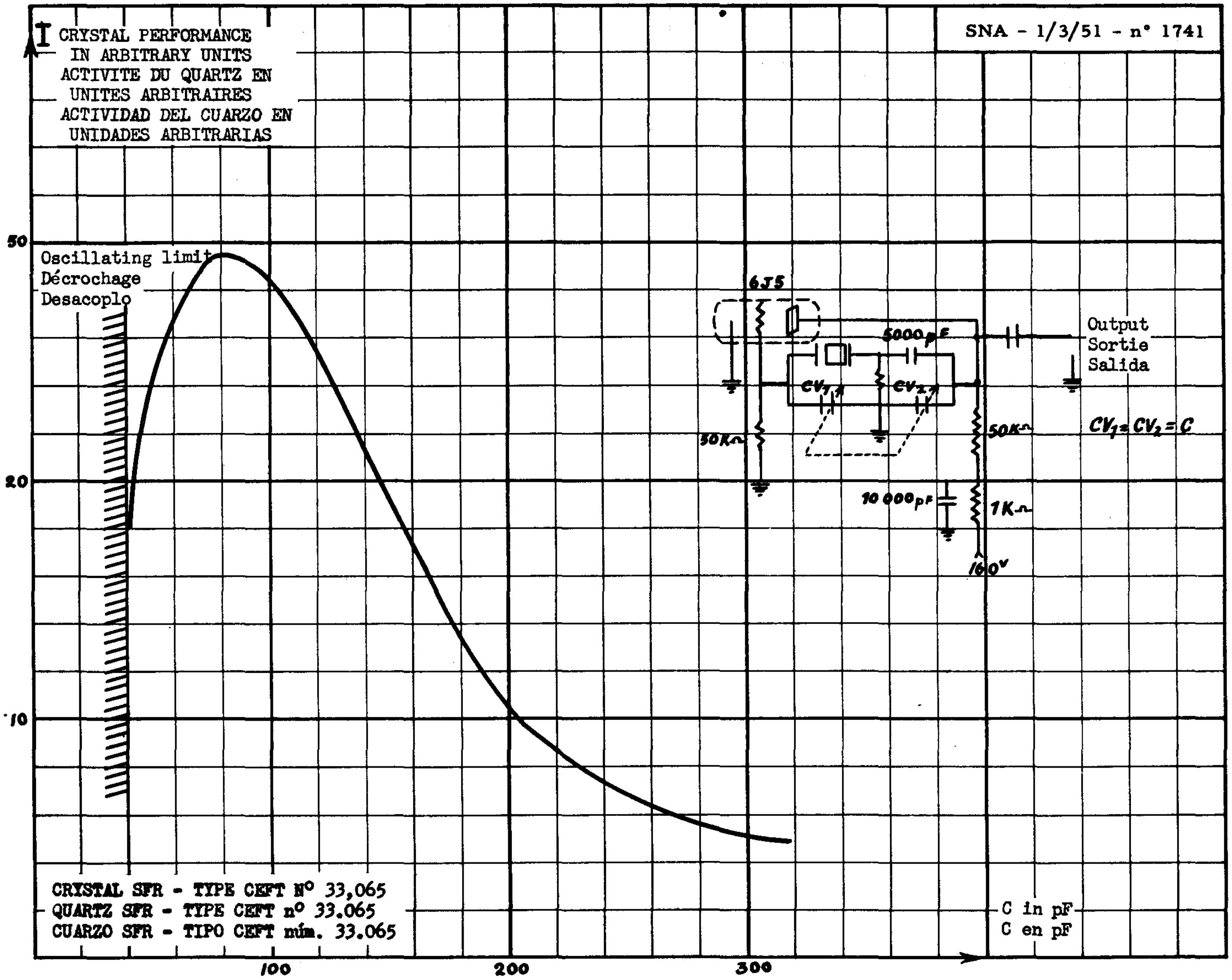


Fig. 9.- CRYSTAL PERFORMANCE VARIATION AS A FUNCTION OF CAPACITIES CV_1-CV_2
VARIATION DE L'ACTIVITE DU QUARTZ EN FONCTION DES CAPACITES CV_1- CV_2
VARIACION DE LA ACTIVIDAD DEL CUARZO EN FUNCION DE LAS CAPACIDADES CV_1-CV_2

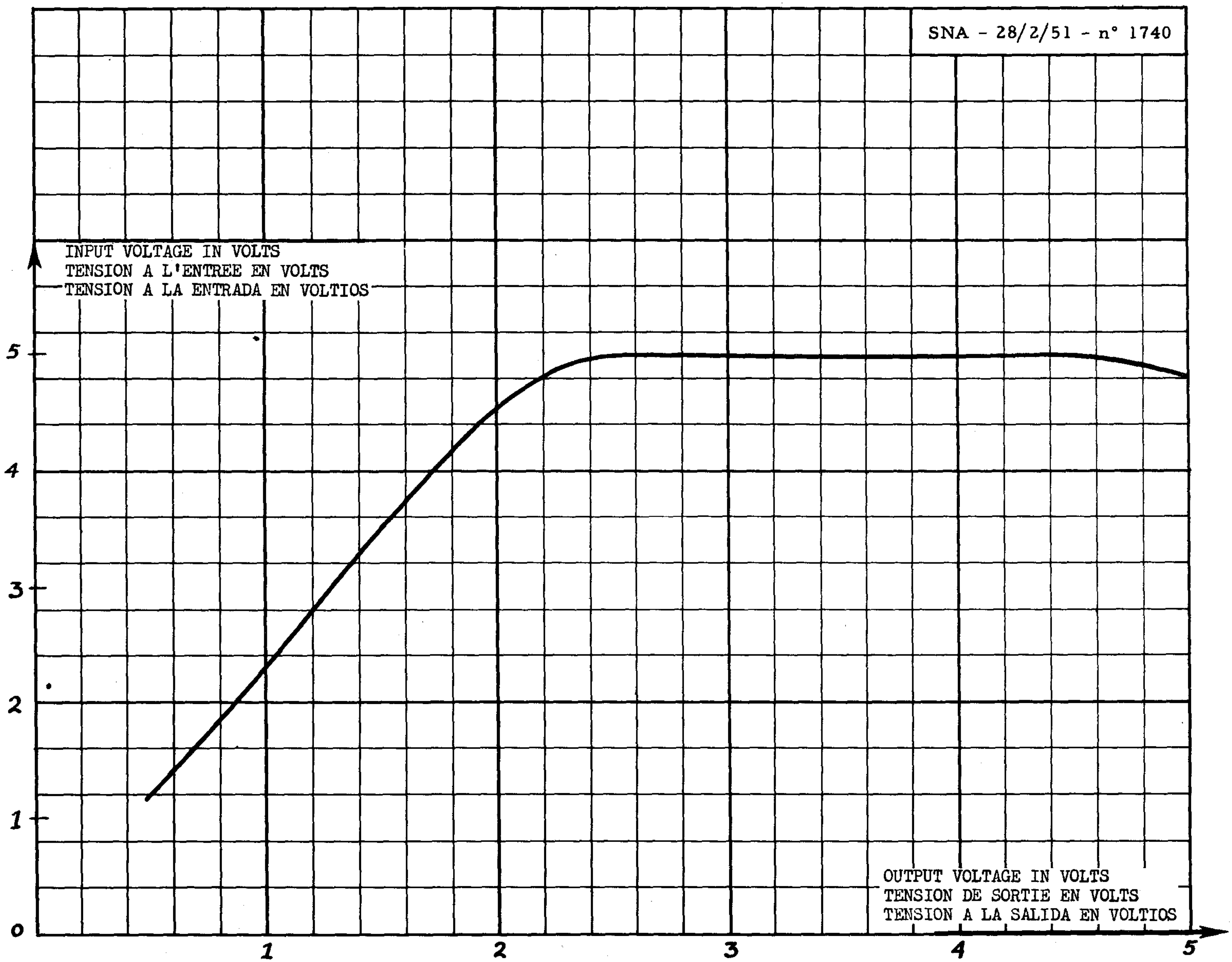


Fig. 10.- LIMITER STAGE REGULATION CURVE
COURBE DE REGULATION DE L'ETAGE LIMITEUR
CURVA DE REGULACION DE LA ETAPA LIMITADORA

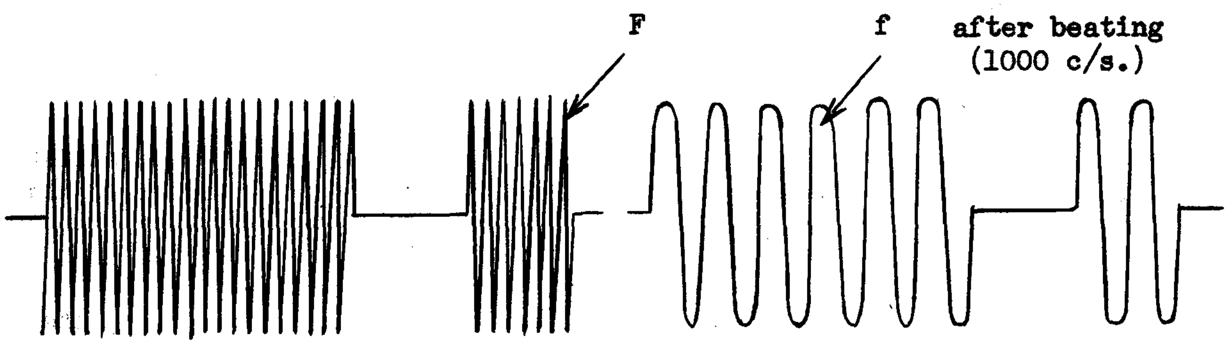
CHAPTER III

RECEPTION TECHNIQUES FOR F_1 WAVES

3.1 F_1 modulation or modulation by carrier frequency shift is only audible if the receiver is fitted with a BFO (Beat Frequency Oscillator). In this case, the frequency tone f obtained after beating is a function of the frequency F of the carrier.

Figure 11

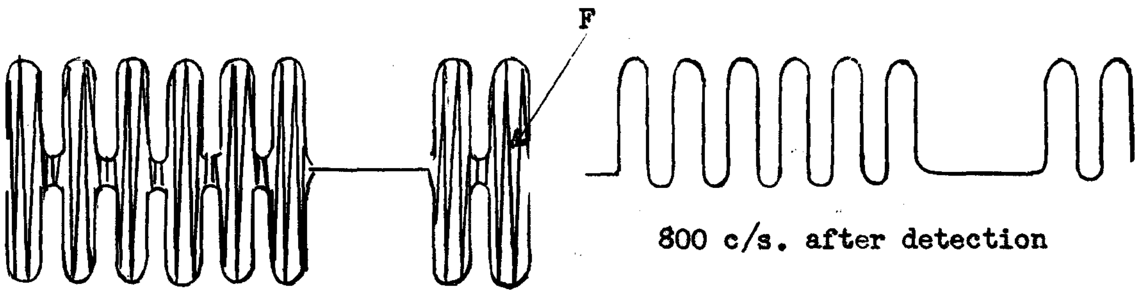
Reception of A_1 waves with a BFO



3.2 The so-called "heterotone" device, the principle of which is to amplitude modulate at low frequency (800 c/s) the continuous wave trains produced from the A_1 modulation, as indicated in Fig. 2, does not enable the F_1 modulation to be heard, since after detection no trace remains of the F frequency waves.

Figure 12

Reception with heterotone



800 c/s. after action of the heterotone

3.3 Reading of the keyed signal

It is necessary to read the keyed identification signal by tone difference. The frequency of the tone received is a function of the tuning of the input circuit.

In order to facilitate reading or more correctly to avoid reading the counter-keying, the setting should be adjusted as follows:

- Ensure that one is on the right side of the beat, namely, that the identification tone is of higher frequency than the mean tone.

- This done, tune the input circuit until the higher tone is more easily audible than the lower tone. Obviously the tuning will vary with the operator, since each ear is more sensitive to a particular tone.

If correctly adjusted, it should be more pleasant to listen to the F_1 signals than to the A_1 signals, since as the carrier is not interrupted, reception of static during the identification is avoided.

3.4 Advantages of F_1 keying

The attention of operators is drawn to the advantages of adopting this keying system.

a) All the advantages of A_1 (range, etc.) with non-interruption of the carrier.

b) Use in the future of Broadcasting Stations as radio beacons.

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CHAPTER IV

TESTS OF THE F_1 IDENTIFICATION METHOD

4.1 Notice to Airmen

In order to test the method, a non-directional beacon with F_1 identification was installed at Le Bourget.

To permit aircraft with ADF's not equipped with a BFO to use the beacon during the testing period, provision was made for alternate keying on A_1 and F_1.

On 4 February the following NOTAM was issued:

NOTAM

LE BOURGET NON-DIRECTIONAL BEACON A_1/F_1 EMISSION

From 6 February 1951, Le Bourget non-directional beacon will transmit, for test purposes, alternated A_1/F_1 identification signals. The operating cycle will be as follows:

1) Identification signal FNB5, transmitted on A_1 every 20 seconds (complete interruption of the 396 kc/s. carrier wave);

2) Series of 3 FNB identification signals transmitted on F_1 continuously during the interval. Frequency: 396.1 kc/s, frequency shift keying: about 100 cycles.

Interval and intersign frequency: 396 kc/s.

The attention of airmen is drawn to the following:

a) The identification signal transmitted on A_1 is the only one audible on receivers provided with a heterotone device. (The signals of this beacon appear unchanged as (A1)).

b) The identification signals transmitted on A_1 and F_1 will be audible on receivers fitted with a suitable beat frequency oscillator (BFO).

4.2 Reports from air crew

From the comments made it appears that the method advocated is entirely feasible.

The main criticism expressed was that at long distances F_1 identification was less audible than A1 identification. However the 'long distance' referred to by air crew on the occasion of the tests exceeded 80 kms. Some observations were also made at a distance of 180 kms (Corbigny), whereas the beacon only had a power of 40 W (required range 60 kms).

On the other hand, while the identification signal is less audible on F_1 than on A_1, the ADF operates better during F_1 keying owing to the fact that during A_1 keying the carrier is interrupted.

4.3 Flight tests conducted by the French Authorities

On 15 and 16 February 1951 a representative of the Service de la Navigation Aérienne participated in flight tests carried out by Air France aircraft FBATQ.

The results obtained can be summarized as follows:

Observation made at Compiègne (60 kms from Paris):

a) Keying entirely audible on the antenna position;

b) ADF operation perfectly in order (10° Swing) during F_1 keying. During A1 keying ADF indications were distorted due to interference from the ONB (Brussels) beacon, range 100 miles, operating on 395 kc/s.

Conclusion

The tests proved satisfactory and confirmed the conclusions of Air France air crew.

SUMMARY OF REPORTS MADE BY AIR FRANCE RADIO OPERATORS

LISTENING TO BEACON FNB5

DATE	ROUTE	AIRCRAFT REGISTRATION MARK	RADIO OPERATOR'S REPORT	COMMENTS
9/2	PS/LO	FBATT	New FNB5 identification is only readable at short distance.	Short distance: vague term.
10/2	PS/BL	FBATV	FNB5: two possible bearings at 180°, on the runway. In flight at 10 kms, 30° variation between FNB5 and FNB.	The variation in bearing between FNB5 and FNB is due to the fact that for FNB5 (on A_1) the carrier is interrupted during identification transmission. Therefore all readings taken at that moment are doubtful.
10/2	PS/LO	FBCUN	FNB5: identification FNB5 readable OK but not as strong as FNB. If badly tuned FNB counter keying is heard.	
11/2	PS/LO	FBATX	Beacon FNB5: at 22.30 hrs. the readability of frequency shift keying signals leaves much to be desired, the comparison is advantageous to the old system of keying.	
11/2	PS/LO	FBCUP	1. FNB5 is read more easily on A_1 than on F_1.	Information lacking in precision.

DATE	ROUTE	AIRCRAFT REGISTRATION MARK	RADIO OPERATOR'S REPORT	COMMENTS
12/2	PS/LO	FBCUP	2. Readability on F_1 does not remain good up to the limiting range. 3. Under QRM better readability on A_1 than on F_1.	What is meant by limiting range?
13/2	NI/PS	FBCUA	FNB5 396 kc/s: using ADF (antenna) QTH Corbigny - on 1000 c/s: both keyings OK; on 800 c/s: frequency shift keying. Nil - continuous dash. A_1 keying: OK.	Information precise and useful. Results satisfactory.
13/2	PS/LO	FBATT	At long distance FNB5 far stronger than FNB.	Information lacking in precision; What is meant by long distance?
14/2	PR/PS	FBCUN	Bearings may be taken on FNB5 at 180 kms using manual D/F: clear 40° swing.	Information precise.
			At 150 kms ADF unstable, 10° to 20° swing (at times 90°).	Results satisfactory.
			FNB5 identification QSA 4 at 180 kms FNB identification QSA 2 at 180 kms. At 60/80 kms identification stable.	
14/2	BL/PS	FBCUP	Le Bourget beacon FNB5 and FNB received at Corbigny.	Information precise. Corbigny is 180 kms from Le Bourget. Results satisfactory.

DATE	ROUTE	AIRCRAFT REGISTRATION MARK	RADIO OPERATOR'S REPORT	COMMENTS
14/2	LO/PS	FBATV	FNB5: Identification FNB (F_1) audible at normal range but makes bearings fluid (taken at night on return from London).	Information to be verified. There is no reason why F_1 keying would cause any inaccuracy in the bearing.
16/2	NI/PS	FBCUM	Listened to FNB5 396 kc/s: QTH Corbigny on 1000 c/s both keyings OK.	Information precise. Results satisfactory.
21/2	PS/LO	FBATV	FNB5 396 kc/s. bearings difficult at night during frequency shift keying. Otherwise OK (if the identification signal were transmitted twice per minute on a continuous dash, would be ideal).	
21/2	PS/PR	FBATZ	Bearings taken from Le Bourget beacon widh ADF while receiving the FNB identification signal satisfactorily: 50 kms. With manual D/F: 160 kms with a play of 35° 100 kms 20° 80 kms 15° 50 kms 10° (squally weather not very suitable for tests).	Information precise. During his test A_1 keying was interrupted. Results satisfactory.
24/2	PS/LO	FBATN	1. Readability F_1 2/5-A_1-5/5. 2. Readability F_1 2/5 at 80 kms and 3/5 very approximately. 3. F_1 readability not as good under conditions of interference.	Results satisfactory.

DATE	ROUTE	AIRCRAFT REGISTRATION MARK	RADIO OPERATOR'S REPORT	COMMENTS
24/2	PB/EABL	FBATX	FNB difficult to identify at 13.00 hrs. I think that at night identification will be difficult outside a radius of 50 kms.	At 13.00 hrs. the aircraft was at Corbigny (180 kms). Results satisfactory.

CHAPTER V

BROADCAST STATION IDENTIFIER

AERONAUTICAL RADIO, INC.
1108 16th Street, N.W.
WASHINGTON D.C.

February 24, 1948

Information
Letter No. 396

Refer to File
No. 03-600-6000

To: SUPERINTENDENTS OF COMMUNICATIONS

Subject: Broadcast Station Identifier

Early in 1946, ARINC re-activated the project for furnishing suitable equipment to provide frequent identification of broadcast stations in order to use these stations as an "en route" navigational aid. This project had been started in 1941, but discontinued during the war. The purpose of the project was to develop equipment for use in the aircraft in conjunction with ADF receiving equipment which would provide the pilot with a continuous identification of the broadcast station. Obviously, the transmission of the code identification must be such as not to be heard by the broadcast listener.

The transmission of the station call letters was accomplished by the use of a code signal of low audio frequency (40 cycles) and low modulation percentage. An airborne unit was developed which operated from the 40 cycles keyed signal of the broadcast station and, in turn, keyed a local 2000 cycle tone. When properly connected to the ADF receiver, the pilot would hear the call letters of the station to which he was tuned.

It was originally planned to modulate the broadcast station 5 per cent with the 40 cycles keyed signal. Tests showed that even at this low percentage of modulation, the 40 cycles tone was detectable in the broadcast. Complaints from listeners made it necessary to reduce the percentage of modulation to 3 per cent in order to avoid interference with the program transmission.

Tests of this method of broadcast station identification revealed that it was quite feasible; but that if it were necessary to reduce the percentage of modulation of the keyed signal to as low as 3 per cent, operation of the device at any great distance would be marginal. Since the use of broadcast stations with this device was being considered for "en route" navigation, the reduction of the distance over which the identifier was useful defeated its purpose. It was for this reason that ARINC recommended that the project be dropped.

It is understood that broadcast stations with continuous identification are being considered for use in let-down procedures. It appears that for this purpose where only a limited range is necessary satisfactory operation may be obtained with low modulation levels. ARINC has on hand two convertor units which were used in the original tests which are available to anyone interested in conducting tests for their own purpose. Circuit diagrams may be obtained upon request.

Obviously, a low percentage of modulation of the keyed signal required so as not to interfere with the broadcast station program will limit the distance at which the station identifier may be heard. This, of course, will neither limit nor interfere with the distance at which the same station may be used for ADF operation, without continuous identification.

It is our opinion that such an arrangement for use in let-down procedures is feasible provided its use is restricted to an area close to the station, probably within the 50 microvolt contour line. However, it is felt that this should not be considered as a general system but rather as a local expedient, since successful operation is dependent on many factors of a particular situation.

F.C. Dyer

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PRICE: $0.15 (Cdn.)	(Montreal)
Equivalents at date of publication:	
50 m/ms	(Cairo)
2.25 soles	(Lima)
1s. 0d.	(London)
1s. 3d.	(Melbourne)
50 francs	(Paris)