DEPARTMENT OF COMMERCE

BUREAU OF AIR COMMERCE

SAFETY AND PLANNING DIVISION

NOTE NO. 5

REPORT ON TESTS AT THE PHILADELPHIA RADIO RANGE

July 14, 1938

[illegible]

July 14, 1938.

REPORT ON TESTS AT THE PHILADELPHIA RADIO RANGE

This report covers an investigation of the operation of the Philadelphia radio range made jointly by representatives of the Safety and Planning Division and Airways Engineering Division. The work described herein was undertaken as a result of memorandums dated May 27 and May 28 from the Chief, Airways Engineering Division to the Chief, Safety and Planning Division, outlining reports of erratic behaviour of the Westinghouse SMRA stations at Allentown and Philadelphia, Pennsylvania.

The principal difficulties encountered at these stations were severe key clicks and inability to secure reciprocal course alignments, because of reradiation of side band energy from the center tower. The question had also been raised of the possible anomalous effects of reradiation from the center tower when courses must be bent to secure the desired alignment. In view of the fact that the Philadelphia range was inoperative pending the completion of the new Philadelphia Airport, it was made available for test purposes to determine methods of properly aligning the courses, and possible remedies for the key clicks.

Key Clicks

The phenomenon of key clicks is caused by transient oscillations in the various networks which make up the radio range coupling system between the transmitter and antennas. Since these networks are very complicated structures a mathematical analysis of their transient behaviour is practically impossible. Consequently there is little to go on when dealing with key clicks outside of a very general qualitative knowledge of their cause.

In tests run on the Hartford radio range during March of this year, a complete absence of key clicks was noted. There were two essential differences between the coupling equipments in use at Hartford and Philadelphia.

12437

In the Hartford equipment provisions were made for operating the link circuit at exact resonance. In the Philadelphia equipment a power amplifier biasing circuit was connected in with the link circuit relay, and no provisions for tuning the link circuit were made. It was reasoned that if the Philadelphia equipment were made as near like the Hartford equipment as possible, the key clicks might be eliminated. This was found to be the case.

The power amplifier biasing circuit appeared to be an entirely unnecessary complication of the equipment and was completely disconnected. This resulted in a slight reduction in key clicks. The link circuit was then resonated by detuning the goniometer primaries and by so doing the key clicks were reduced practically to the vanishing point. Since operating this circuit at resonance has advantages other than the possible reduction of key clicks, it has been recommended in a memorandum to the Chief, Airways Engineering Division from the Chief, Safety and Planning Division that all of this type equipment be modified to incorporate link tuning condensers.

Effect of Center Tower on Course Alignment

Due to the mutual impedances between the elements of the radio range antenna system, it is to be expected that current of side band frequency will be caused to flow in the center tower by induction from the corner towers, except under very special conditions. Also any current of side band frequency in the center tower will in general affect the alignment of the courses.

Consider an opposite pair of corner antennas denoted by 1 and 2 together with the center antenna denoted by 0. It will be assumed that the mutual impedances are the same between the center antenna and either of the corner antennas ie, $Z_{01} = Z_{02} = Z_M$. The current induced in the center antenna by the corner antennas will then be in general

$$I_o = \frac{Z_M}{Z_o} \sqrt{I_1^2 + I_2^2 + 2I_1 \; I_2 \; \cos \phi} \qquad (1)$$

where ϕ is the phase difference between the current I_1 and I_2. If ϕ equals 180° as would be the case for reciprocal courses then (1) becomes simply

$$I_o = \pm \frac{Z_M}{Z_o} (I_1 - I_2) \qquad (2)$$

If the antennas are properly tuned the currents I_1 and I_2 will be equal provided the resistances of the towers are equal, and I_o will vanish. Thus when ϕ equals 180° it is always possible to make I_o equal o by the simple expedient of equalizing the resistances of all of the corner towers. In what follows it will be assumed that this has been done.

Considering now the case where $\phi \neq 180^\circ$ but $I_1 = I_2 = I$ (1) becomes

$$I_o = \frac{2Z_M \, I}{Z_o} \cos \frac{\phi}{2} \qquad (3)$$

Let $Z_M = P_M \, E^{i\alpha_m}$

$Z_o = P_o \, E^{i\alpha_o}$

Then

$$\frac{I_o}{I} = 2 \cos \frac{\phi}{2} \; \frac{P_M}{P_o} \; E^{i\,(\alpha_M - \alpha_o)} \qquad (4)$$

The ratio of the center tower current to corner tower current is given in phase and amplitude by (4). If the quantities Z_M and Z_o are determined by measurement or otherwise it will be possible to calculate the exact affect of the center tower current upon the course alignment. In the attached curves the amount of course shift which will occur for various ratios of $\frac{I_o}{I}$ is shown for various phase angles between 0 and 90 degrees. It is seen that the maximum shift occurs when $\alpha_M - \alpha_o = 90^\circ$ and that no shift occurs when $\alpha_M - \alpha_o$

equals o. In practice it is possible for $\alpha_M - \alpha_o$ to have any value between 0 and 90° and the value which it will have is difficult to determine unless direct measurements of the quantities Z_M and Z_o are made. Furthermore, there is no way of preventing variations of α_o and hence of $\alpha_M - \alpha_o$.

In the tests at Philadelphia the currents in all of the antennas were equalized and the courses flight checked. Under these conditions with no side band current in the center tower opposite courses were found to be exact reciprocals as would be expected. Next the artificial lines were adjusted to make ϕ equal 18 degrees and another flight check made. Although with this phase difference the current ratio was found to be $\frac{I_o}{I} = .045$ no anomalous bend in the courses was observed which leads to the conclusion that the quantity $(\alpha_M - \alpha_o)$ must have been less than 15 degrees as the accuracy of checking courses was approximately 1 degree. Thus under the conditions at Philadelphia no difficulty would be encountered in aligning courses as the actual alignment would coincide with the calculated alignment within the limit of observational error. This is considered as being purely a matter of chance, however, and not to be interpreted as meaning that trouble will never be encountered at other stations.

From the magnitudes of the impedances Z_M and Z_o which will likely be found at most stations, it is not anticipated that a great deal of difficulty will be experienced in securing the desired alignment of courses even though actual and calculated alignments do not coincide. The problem will merely be reduced to one of trial and error which has always been the case to a certain extent. Certainly no difficulty will be had in securing reciprocal alignments if the tower currents are equalized as they should be under any circumstances.

It is recommended that further investigation of the effect of center tower reradiation upon the alignment of the courses be deferred until actual difficulty arises in the field. Investigation of such a case would be much more instructive and provide more data to work on than could be secured under the limited experimental conditions at Philadelphia.

D. M. Stuart
Radio Engineer
Safety and Planning Division

P. Caporale
Assistant Radio Engineer
Airways Engineering Division

DMS:jam/hf

12437

APPENDIX

Since this report was written the question of the exact method to employ in equalizing antenna currents has arisen. Accordingly this short note covering the method to be used is appended.

It is obvious that if the resistances of the corner towers are equal their currents will be equal provided the stabilizing process has been carried out properly and the antennas are not too far off tune. This suggests at once the incorporation of a variable resistor unit in each tuning house with a control knob on the front panel so that resistances may be equalized during the tuning up process. The resistor to be used should have a maximum value of approximately 2.0 ohms with a current carrying capacity of not less than 6.0 amperes. It should be variable from zero to maximum value in steps of not more than .05 ohms and should be connected directly in the antenna circuit. The resistor need not have any particularly great constancy of value as will be explained here.

When the stabilizing process is carried out the result is to make the transfer impedance relating the line sending end voltage to the antenna current independent of antenna tuning, i.e.

$$Z_{o2} = \frac{E_o}{I_2} = jX_M \cos \theta$$

where X_M is the mutual reactance of the transformer windings and θ is the electrical length of the transmission line. Thus it is seen that if the value of X_M is the same for all antennas their currents will be equal regardless of antenna resistance or reactance since it is assumed that equal lengths of line run to each tower. However, when the line impedance is matched the value of X_M at each tower is made

$$X_M = \frac{\sqrt{Z_o R_2}}{\cos \theta}$$

where Z_0 is the characteristic impedance of the line and R_2 is the antenna resistance. If the resistances R_2 are not the same for all towers the transformer mutual reactances and hence the currents will be unequal. It is apparent then that unequal resistances will not of themselves directly produce unequal currents. The effect is brought about by the unequal values of X_M arrived at by the tuning procedure which we have adopted. Furthermore, it is obvious that if the resistances were equalized only during the tuning up process equal currents would persist at any subsequent time even though widely different resistances were inserted. Hence the requirements of constancy of the resistance to be chosen are not at all severe and should be met by a wide variety of commercial products.

It might be pointed out in concluding that increasing the resistance of the antenna circuits will provide greater stability of course alignment, especially at stations where the goniometer is set near zero or ninety degrees. Since in all cases ample power is available in the sideband channel of the transmitter it is considered desirable to operate the antennas at resistances of approximately 5.0 ohms.

DMS

DMS:jam

Curves Showing Course Shift Against The Ratio of Side Band Current in the Center Antenna to Current in the Corner Antennas For Various Phase Angles Between These Currents. These Curves Apply to 500 Foot Tower Spacing and a Frequency of 369 Kilocycles.