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Short Note

ON AN IMPROVED MSK CONVERTER

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Recently, some or all of the U.S.Navy transmitters have changed a form of code from FSK(frequency-shift-keying) to MSK(minimum-shift-keying). With the change of the form of code, the existing VLF phase tracking receivers have become unable to track a phase of VLF signal with MSK code. For the purpose of tracking a phase of MSK signal with the existing VLF tracking receivers, a MSK converter was developed.

The MSK system is a type of frequency-shift-keying in which the bit frequency is equal to twice the difference frequency. In consequence, if a bit is transmitted at frequency f_1, then one bit at frequency f_2, and a third bit at frequency f_1 again, the phase of frequency f_1 during the third bit will differ by 180° from what it was during the first bit. Therefore, there is no coherent "carrier" at either of two frequencies(See Fig. 1.). This is the reason why the existing VLF tracking receivers have become unable to track a phase of VLF signal with MSK code.

By a process of frequency doubling, those transmissions at zero phase and those at 180° are restored to equal phase at the second harmonic frequency. Phase tracking of the 2nd harmonic with a existing VLF tracking receiver is then possible. The MSK converters[1] using the above principle are sold now at a market, the block diagram of which is shown in Fig. 2. In the MSK converter is used a doubling circuit generating a large 2nd harmonic content by the limiting and amplification of MSK signals. Therefore, the MSK converter can track a phase of MSK signal, but makes a sacrifice of a carrier amplitude information due to the limiting.

As simultaneous records of both phase and amplitude variations are required for investigations of VLF propagation, an improved MSK converter to obtain these records simultaneously has been developed.

In this paper, we describe the improved MSK converter, the block diagram of which is shown in Fig. 3. What differs from the marketing converter is to adopt a different type of frequency doubler. The improved MSK converter, the schematic diagram of which is shown in Fig. 4, is equiped with a full-wave rectifier circuit with a dynamic range of about 50 dB. Its output signal is fed to the input of a existing VLF tracking receiver and is converted into sinusoidal waves of the 2nd harmonic frequency at the RF tuning circuit of receiver(See Fig. 5.). Then, the phase tracking of the 2nd harmonic frequency is again possible here. In addition, what is important is that a carrier amplitude output can be obtained without significant distortions by using the particular rectifier.

We give here two examples of records of diurnal variations of both phase and amplitude obtained with two different types of converters for the NWC signal from Australia(See Fig. 6(a) and (b)). As is seen from the records of phase in Fig. 6(a) and (b), a diurnal variation is similarly obvious for each of records with two different types of converters. Therefore, we think that two different types of converters are acting equally well in tracking a phase of MSK signal. On the other hand, there exists a remarkable difference between two carrier amplitude records. From the amplitude record of the carrier passing through the marketing converter shown in Fig. 6(b), a diurnal variation can not be seen because of the absence of the coherent amplitude output. While, from the amplitude record of the carrier passing through the improved converter shown in Fig. 6(a), can be seen obvious diurnal variation. As described above, simultaneous records of both phase and amplitude variations can be obtained with the improved MSK converter.

Finally, we conclude that it is more useful for investigations of VLF propagation to adopt the improved MSK converter than the marketing one.

Acknowledgment - We wish to express our sincere thanks to Prof. T. Nakai for his detailed comments and useful suggestions.

Reference

1. Operational Manual for 599 MSK Converter, Tracor Instruments.

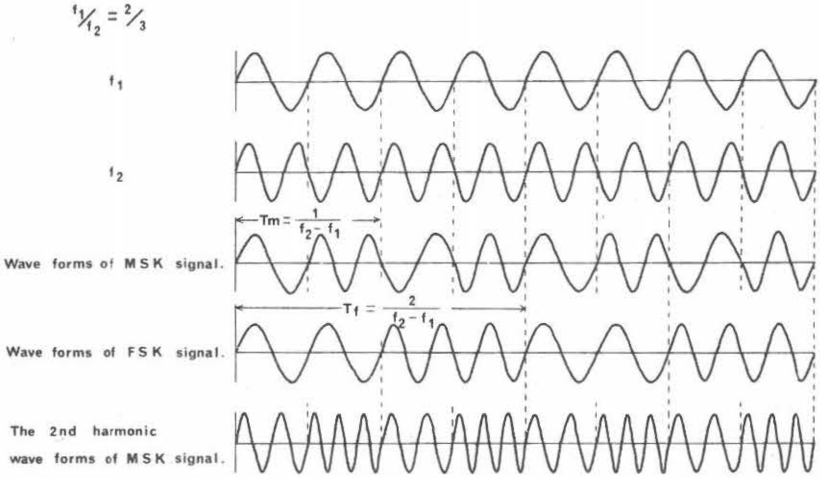

Fig. 1. The phase relationship among FSK code, MSK code and 2nd harmonics of MSK code signals.

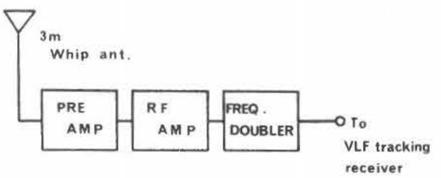

Fig. 2. The block diagram of the marketing MSK converter.

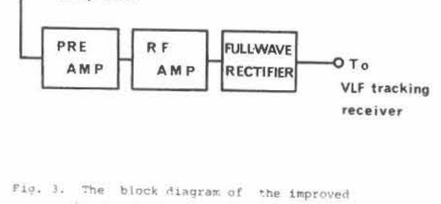

Fig. 3. The block diagram of the improved MSK converter.

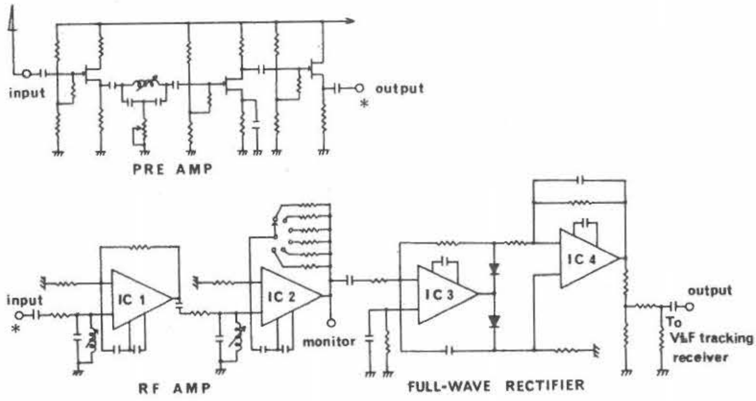

Fig.4. The schematic diagram of the improved MSK converter.

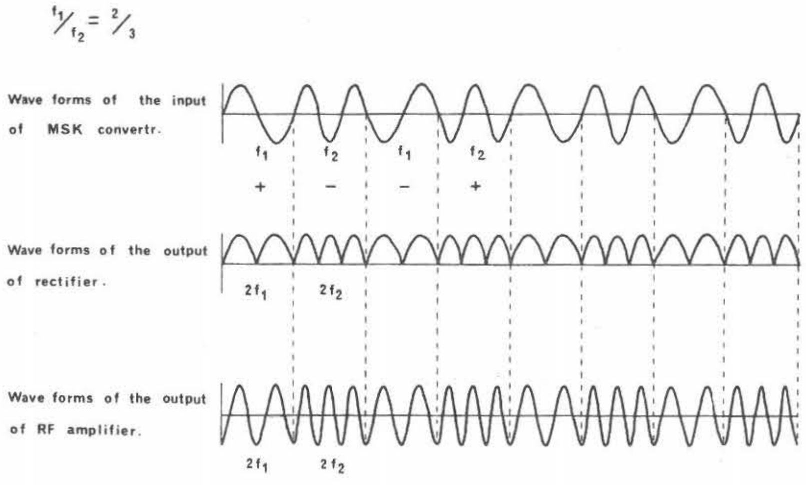

Fig. 5. The phase relationship among each circuits of the improved MSK converter.

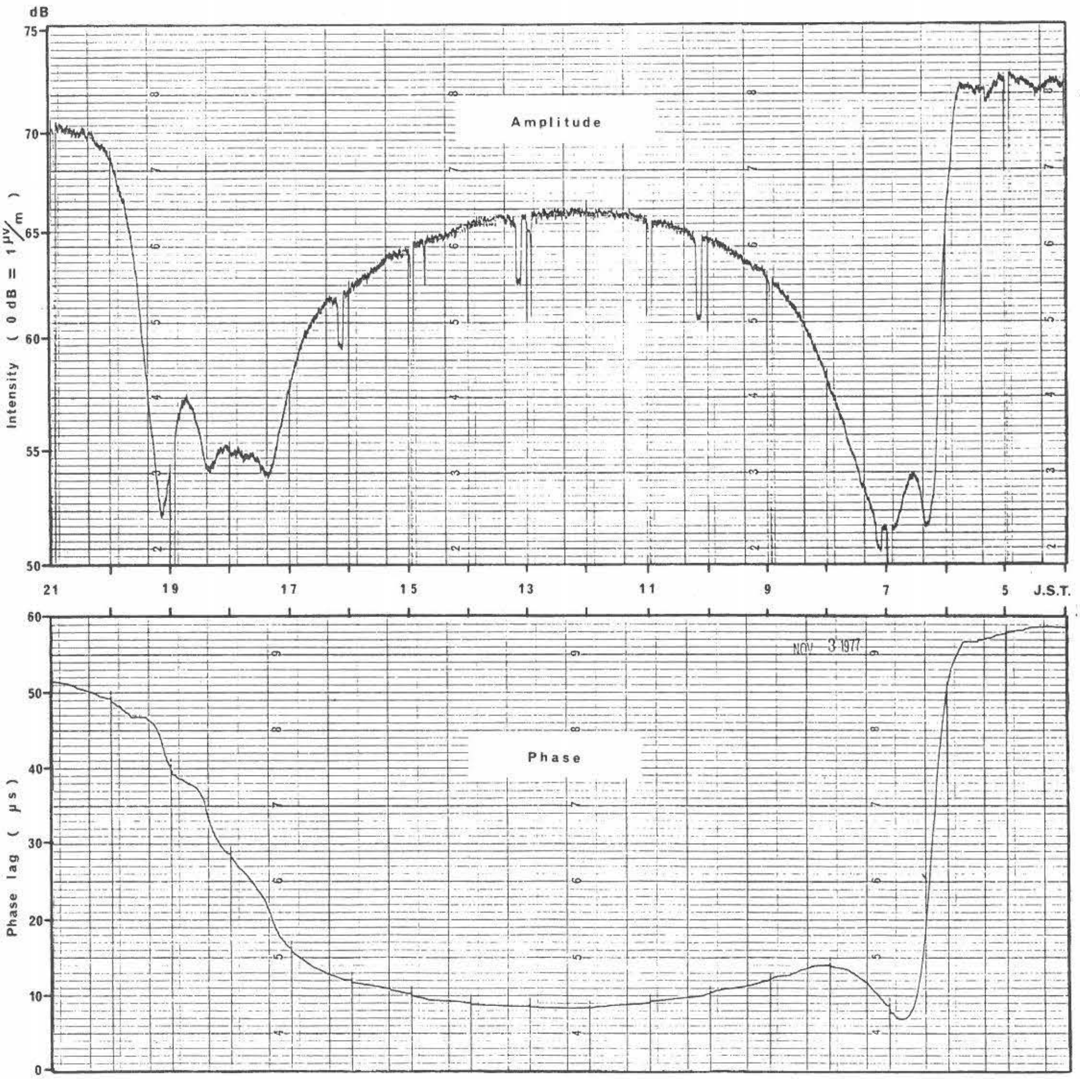

Fig. 6. (a) Diurnal variations of both amplitude and phase obtained by the improved MSK converter for NWC signal (22.3 KHz) received at Toyokawa on Nov. 3, 1977.

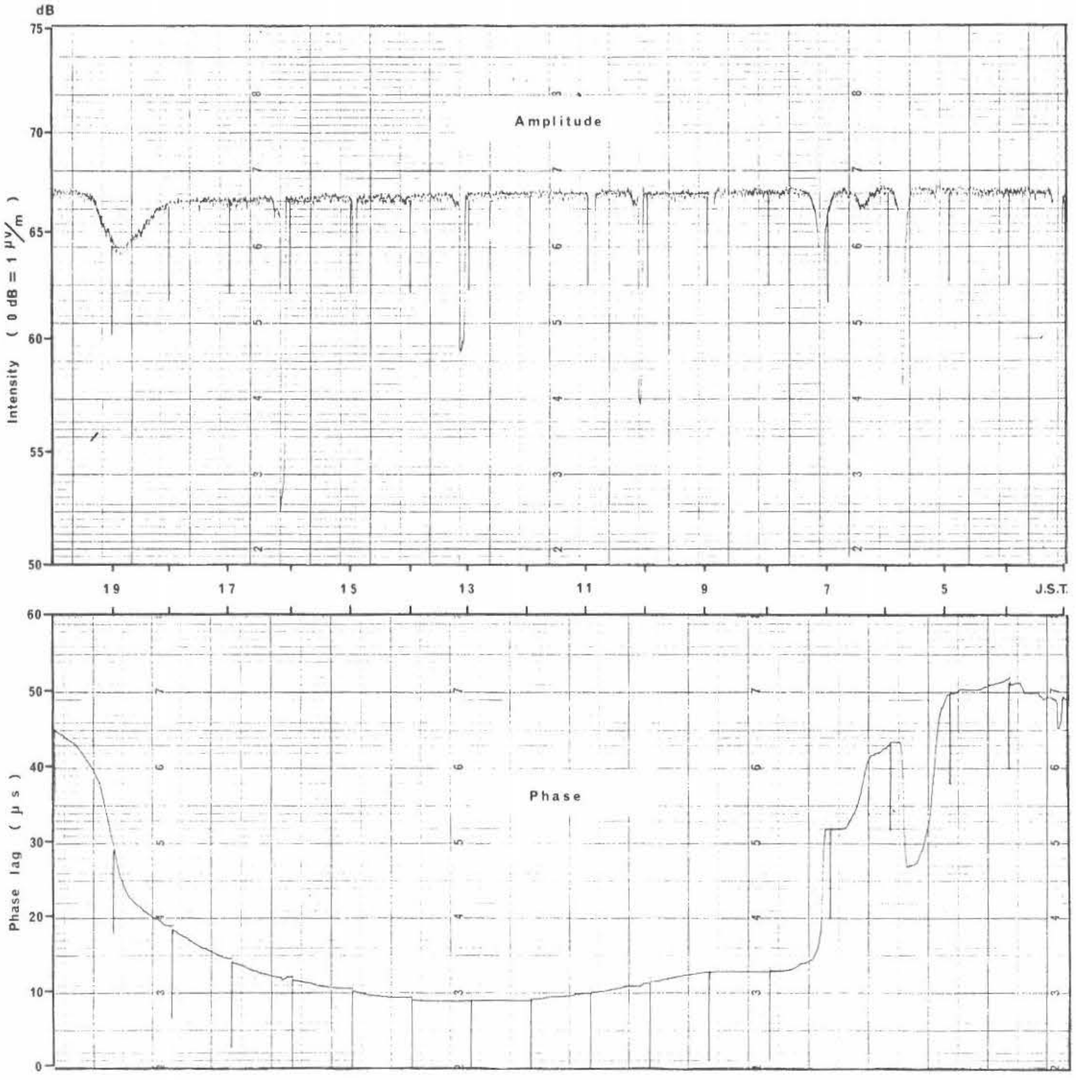

Fig. 6. (b) Diurnal variations of both amplitude and phase obtained by the marketing MSK converter for NWC signal (22.3 KHz) received at Toyokawa on Aug. 11, 1977.