Input paper: [[1]](#footnote-1) ENAV21-11.20

Input paper for the following Committee(s): check as appropriate Purpose of paper:

**□** ARM **□** ENG **□** PAP **⌧** Input

**⌧** ENAV **□** VTS **□** Information

Agenda item [[2]](#footnote-2) (from agenda) 11

Workplan Task Number / Technical Domain 2 …………………………………

Working Group WG 3

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Synchronization Waveform Design

# Summary

The present document provides a VDES-SAT synchronization word (or sync word for short) design. The proposed sync word not only possesses better autocorrelation properties but better PAPR than the current sync word design in M.2092 [1] as well. Although the use of -QPSK helps improve the PAPR or cubic metric of the sync word in [1], it at the same time degrades the autocorrelation performance. The adoption of this waveform as the VDES-SAT sync word is therefore recommended.

## Purpose of the document

The Committee is requested to note the contents of this document and consider the results of the technical requirements study in the VDES-SAT synchronization word selection process.

## Related documents

None.

# Background

As defined in [1], a transmission burst includes ramp up, synchronization word, data, ramp down and guard time as shown in Figure 1. The synchronization word is used in the VDES satellite system to detect the presence of an ongoing transmission and the corresponding timing and frequency. This requires the sync word waveform to possess a good autocorrelation property. This input document provides a synchronization waveform design for possible use as VDES-SAT sync words.



Figure 1 Illustration of a transmission burst

# Discussion

The challenge of the detection of the sync word lies in the fact that there may exist a large Doppler frequency offset (e.g.,  kHz) between the transceivers during detection as a result of the relative movement between a satellite and a ship. This frequency offset introduces a fast phase ramp in the received signal which destroys the correlation property between the received signal and the local waveform template at the receiver. Differentiation is a well-known technique for removing the phase component from the received signal, and is thus assumed to be performed before correlation can be carried out [1].

In [1], the sync words with length  and 48 are designed for best autocorrelation for differential detection. The sequence used to generate sync word of length 27 is provided:. It is then either BPSK modulated or -QPSK modulated to form the sync word . For -QPSK modulated sync word, the bit ‘1’ in the sequence is mapped to -QPSK symbol  or 1; the bit ‘0’ in the sequence is mapped to -QPSK symbol  or -1.

## Sync word selection

Zadoff-Chu (ZC) sequence [2][3] possesses an ideal periodic autocorrelation property for a given root, i.e., zero for all lags other than zero,

.

A ZC sequence takes different forms depending on the length of the sequence, i.e.,

，

when  is odd, and

，

when  is even, where the root of the sequence  is relatively prime to .

Assume  is the original transmitted sync word, where  is the length of the sync word. Since correlation is performed after the differential operation, we have the following relationship between the sync word and the ZC sequence



Thus, the sync word can be written as



Assuming , the sync word can be generated as



which is shown in Figure 2.



Figure 2 Illustration of sync word generation using a ZC sequence

## Performance evaluation

Figure 3 illustrates a sync word detector at the receiver, where the differentiation operation is first performed before the correlation is calculated.



Figure 3 Illustration of a sync word detector

Figure 4 shows the output of the sync word detector at different timing offsets, where the sync word is of length . Equation is used to generate the corresponding ZC sequence for the proposed sync word with  and . We observe from Figure 4 that the proposed sync word shows lower side lobes compared to the sync word given in [1], either BPSK or  -QPSK modulated.

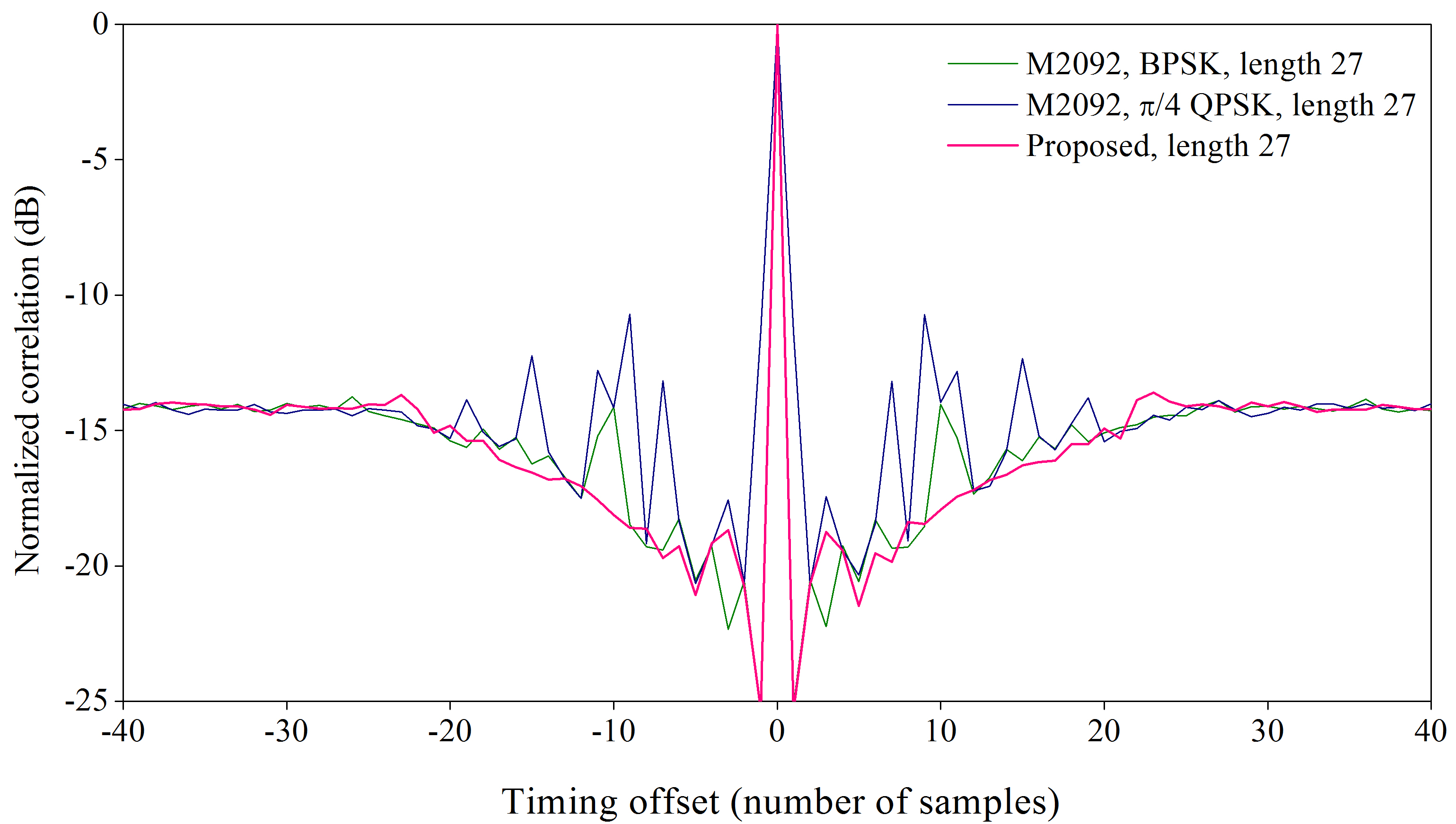


Figure 4 The output of the sync word detector in response to a transmission burst (Figure 1) in the absence of receiver noise, where the sync word is of length .

As ZC sequences have ideal autocorrelation properties, and unified mathematical expression, the sync word can be generated with arbitrary lengths and well defined mathematical properties. Another example of the proposed sync word is shown in Figure **5**, where the length of the sync word equals 48. The corresponding ZC sequence is defined in with  and .

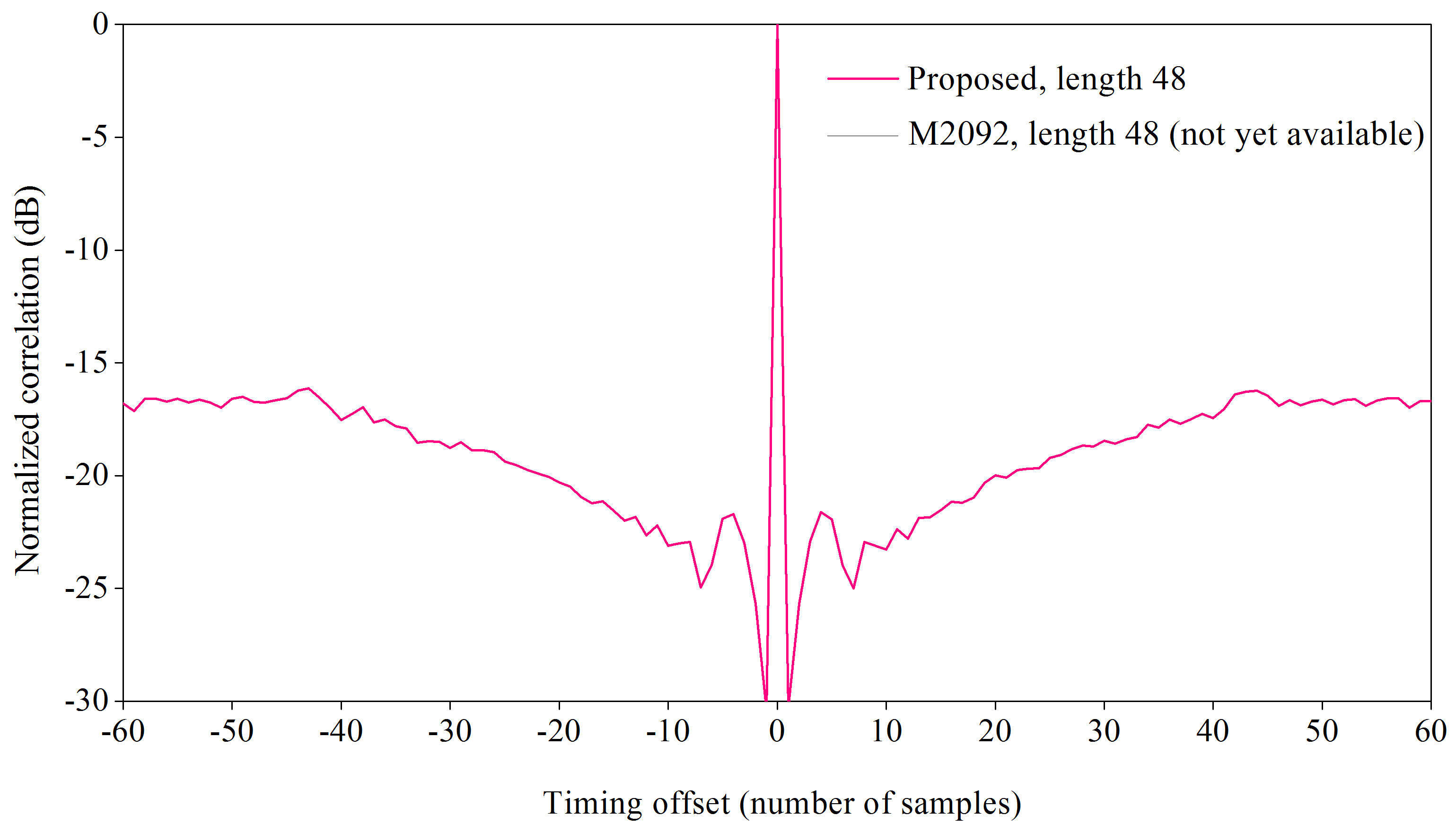


Figure 5 The output of sync word detector in response to a transmission burst (Figure 1) in the absence of receiver noise, where the sync word is of length .

## PA efficiency

The cubic metric (CM) of the sync word () is shown in Figure 6. We observe from Figure 6 that the proposed sync word has improved CM compared to the sync word given in [1], either BPSK or  -QPSK modulated. It is seen that the use of -QPSK helps improve the CM of the sync word in [1] but at the same time degrades the autocorrelation performance as shown in Figure 4.

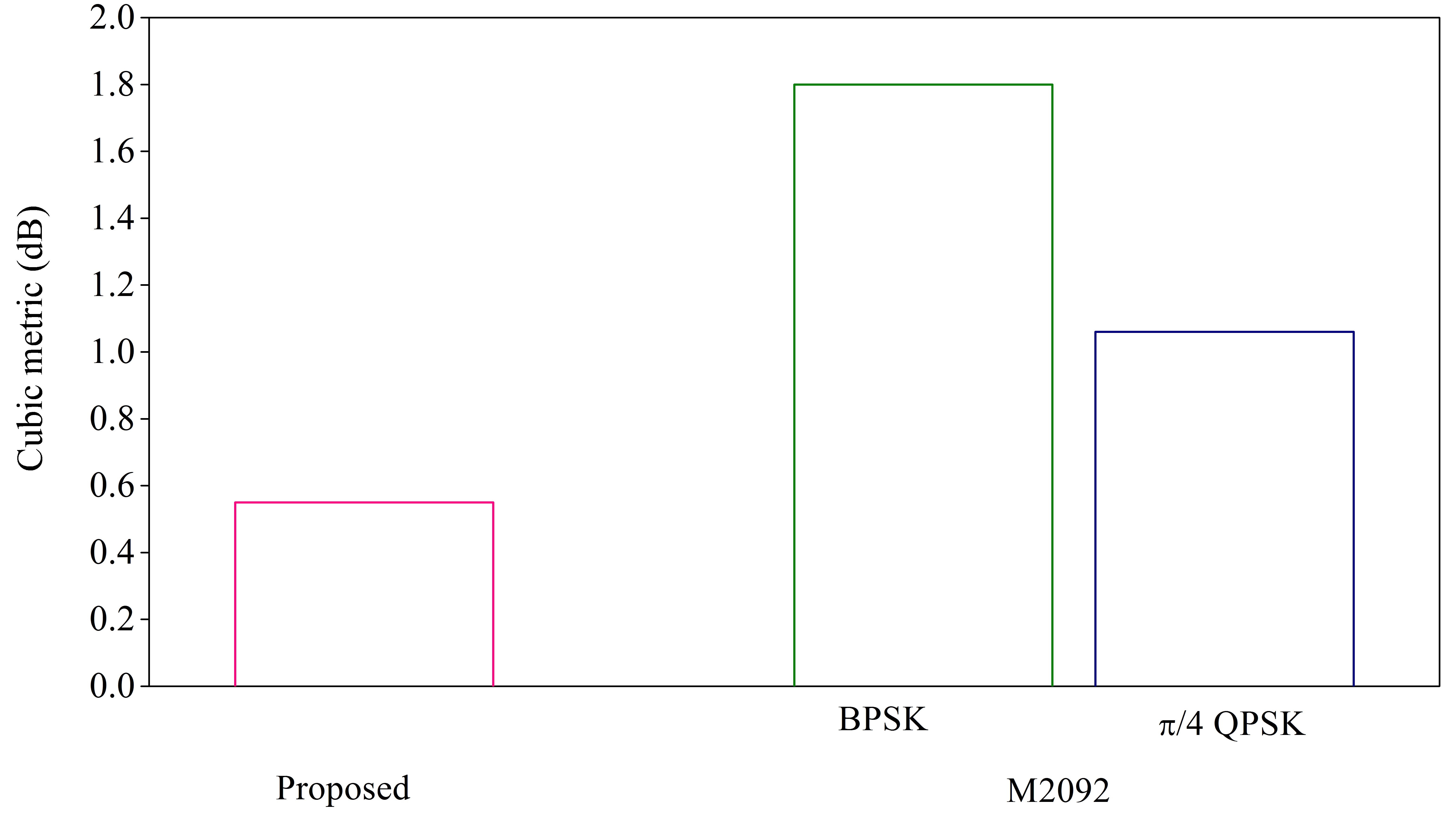


Figure 6 Cubic metric comparison

# References

1. Recommendation ITU-R M.2092-0
2. M. Hua, M. Wang, K. W. Yang, X. You, F. Shu, J. Wang, W. Sheng, and Q. Chen “Analysis of the frequency offset effect on random access signals”, IEEE Trans. Commun., vol. 61, no. 11, pp. 4728–4740, Nov. 2013.
3. M. Hua, M. Wang, K. W. Yang, and K. J. Zou “Analysis of frequency offset effect on Zadoff-Chu sequence timing performance”, IEEE Trans. Commun., vol. 62, no. 11, pp. 4024–4039, Nov. 2014.

# Action requested of the Committee

Review and adopt.

1. Input document number, to be assigned by the Committee Secretary [↑](#footnote-ref-1)
2. Input papers should be assigned to a work task as listed in the Committee work plan which is available in input papers. Leave open if uncertain but consider how the paper is to be processed if not relevant to a work task [↑](#footnote-ref-2)